Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

A TECHNICAL STUDY OF INSECTS AFFECTING THE ELM TREE IN SOUTHERN CALIFORNIA

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BULLETIN 821

How to use this bulletin

For the person not trained as an entomologist, a few suggestions may be helpful.

First: Identify the insect or its damage to the elm tree. Compare the insect at hand with the main categories in the Contents. Use the photographs to assist in this identification.

Second: Read about the insect on the indicated page in the text. This should confirm the identity as well as supply interesting points about the insect's habits and necessary information on control.

Third: Specific directions to control the insect begin on page 21.

Note: This bulletin does not list all the insects that have been recorded on elm but only discusses those with which the authors have had some original experience. Generally the more important insects are included.

CONTENTS

PAGE

SUCKING INSECTS 4

Apache cicada, *Diceroprocta apache* 4
Woolly elm aphids, *Eriosoma* species 6
European elm scale, *Eriococcus spurius* 6
European fruit lecanium, *Lecanium corni* 8
Brown elm scale, *Lecanium canadense* 11

LEAF-CONSUMING INSECTS 11

Spiny elm caterpillar, *Nymphalis antiopa* 13
Elm leaf beetle, *Galerucella xanthomelaena* 13

BORING INSECT 16

Smaller European elm bark beetle, *Scolytus multistriatus* 16

CONTROL OF ELM INSECT PESTS 21

LITERATURE CITED 22

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FEBRUARY 1966

A Technical Study of Insects Affecting the Elm Tree in Southern California[1,2]

Leland R. Brown and Clark O. Eads

Graceful" and "majestic" are terms often used to describe the elm tree, especially the mature, native American elm with its tall, attractive, vaselike form. Other elms, such as the widely planted Siberian and the Chinese elms, are not so tall, but adapt to a variety of growing conditions, grow rapidly, and offer shade in a comparatively short time. The Chinese elm offers an especially dense foliage. For these reasons both Asiatic elms, particularly the Siberian, have been widely planted in arid southern California and its desert-like, inland valleys. All these elms may be found around the home, along the parkways of our streets, and in parks. The smaller types, such as the Chinese elm, are more common in the smaller areas around the home, in patios; the larger types, such as the American elm, are found more commonly in the spacious park areas.

Southern California elms are not affected by as many insect pests as the elms in the eastern United States (Herrick, 1935), but the pests we do have can be important. Often insect problems of our elm trees are secondary in importance to other serious conditions affecting the elm, such as drought. Drought can make the elm more attractive to attack by insects, for instance the smaller European elm bark beetle. Good horticultural practice in southern California will therefore stress adequate irrigation, although the grower usually turns to spraying when something goes wrong.

Mathias and McClintock (1963) list six elm species grown in Califorina for ornament and shade: *Ulmus americana* L., American elm; *U. crassifolia* Nutt.; *U. glabra* Huds., Scotch elm, Wych elm; *U. parvifolia* Jacq., Evergreen Chinese elm, Chinese elm; *U. procera* Salisb., Buisman elm; *U. pumila* L., Siberian elm.

The Siberian elm appears to be the most commonly planted elm in southern California, followed closely by the Chinese elm; the American elm is perhaps next most common. The only member of the elm family (Ulmaceae) listed by Jepson (1923, 1925) as being native to California is a single species of hackberry: the western hackberry, *Celtis mississippiensis* Bosc. The only hackberry Mathias and McClintock list as being used as a woody ornamental plant in California is *Celtis occidentalis* L. The only other ulmaceous ornamental tree listed by them is the Japanese zelkova, or Japanese keaki elm, *Zelkova serrata* (Thunb.), a good but not very popular ornamental tree.

For a more general discussion of sucking, leaf-consuming, and boring insects, and for suggestions on spraying equipment, formulations of insecticides, and precautions with insecticides, as used on large trees in a home yard, park or parkway planting, see Brown and Eads (1965).

[1] Submitted for publication January 22, 1965.

[2] The authors began these studies on the Los Angeles campus of the University of California in 1949 and continued them on the Riverside campus beginning in 1960.

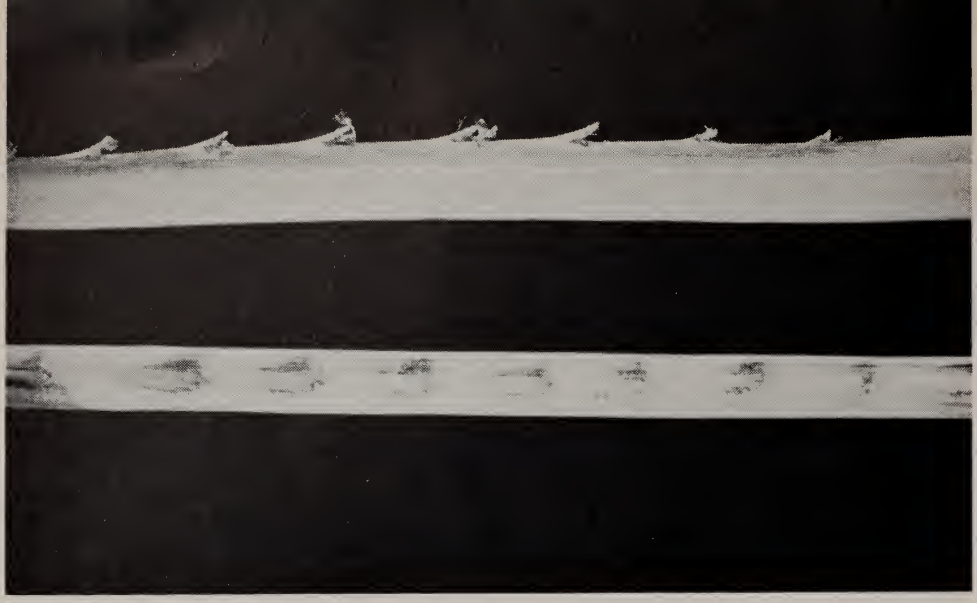


Fig. 1. Apache cicada. Numerous egg-laying punctures on fruiting stem of date. Damage on elm and other plants is similar. (x 3.8)

SUCKING INSECTS

Apache cicada

Diceroprocta apache (Davis), the apache cicada (Homoptera: Cicadidae), is a sucking insect, but its primary injury to the elm tree results from its laying eggs in the tissue of the twigs and smaller limbs (fig. 1). Such twigs may die, but even more important are the following events which are represented here as an hypothesis, or a plausible explanation, of what may occur.

While the elm tree is still dormant the female cicada (fig. 2) lays her eggs (fig. 1) in the tissues. The weather becomes warmer, the sap rises in the tree, reaches the oviposition punctures in the limbs and twigs, and the twigs bleed. Fermenting organisms, perhaps present on the bark and in the air, cause the sap in the wound to ferment, and this attracts Drosophilid (or vinegar) and other flies, beetles, wasps and bees. The Drosophilid flies bring in more fermenting organisms. The fermenting extends further beneath the bark, and the process evidently generates so much pressure that miniature "explosions" occur. Such bigger wounds bleed even more profusely, and attract more Drosophilid flies, so that the wounds appear to be crawling with larvae. Large quantities of fermenting sap may flow down the trunk until it appears completely wetted with the sticky, sour-smelling, and sometimes frothy fluid. Enough fluid may have dropped to the ground to make it look thoroughly wetted by it. This condition is called "slime fluxing" (Pirone, 1948). Often the limb area beyond these bleeding wounds will die. Evidently the elm tree is more likely to exhibit such fluxing—from any wound, not only cicada punctures—than most other genera of trees.

We have observed these events several times in southern California. When cicadas were controlled by insecticidal sprays, the incidence of bleeding lessened, which suggests that the events are related. These observations were made in the more arid parts of southern California, because the apache cicada is found only in these dry locations. When we observed fluxing of elms in other more humid locations, the extent of the bleeding was not so great as in the drier areas.

Fig. 2. Lateral, dorsal, and ventral views of females of Apache cicada; the ovipositor may be seen on the top and bottom specimens. (x 1.4)

This cicada-induced fluxing has been observed on lining-out nursery stock as well as mature trees, and so far only on Chinese and Siberian elms. The apache cicada oviposits in other plants, too, such as in citrus (Quayle, 1941), dates (Stickney *et al.*, 1950), asparagus (Moulton, 1931), as well as in native plants, such as mesquite.

The body of this cicada (fig. 2) is about 1 inch long. The wings, when extended, are about 3 inches from tip to tip. Body color varies from the more common blackish- or greenish-brown to the less common yellowish-brown; the hind margin of the pronotum displays a prominent dull yellow band. The costal margin (at the lower edge of the wing in the top specimen of figure 2) is also dull yellow. The immature stage or nymph (fig. 3) is rather evenly brown colored, and in keeping with its subterranean existence has the foreleg strongly modified for digging; especially is the coxa elongated and the femur shortened and thickened. The eggs, inserted in the plant tissue, are nearly white, spindle-shaped, and elongate.

Fig. 3. Subterranean nymph; note well-developed forelegs for digging. (x 3.0)

According to Quayle (1941) the life cycle of the apache cicada requires two years for completion (some cicadas are notably long-lived—17 years in one case). Stickney *et al.* (1950) gives the most detailed account of its habits: the nymphs (fig. 3) crawl out of the ground in the largest numbers in late May or early June, although many adults may be noticed in mid-April (the earlier emerging adults are possibly the greatest source of harm to elms). Like all cicadas the nymph crawls slowly up the plant for a few feet, and then while resting on the bark, the dorsum of the thorax splits, and the adult crawls out of the old nymphal shell. After waiting briefly for the wings to expand and dry, the cicada is ready to fly. Presumably shortly thereafter they mate, and the female begins to insert eggs (fig. 1) into the hard tissue of the host plant with her sharp, awl-like ovipositor. Stickney *et al.* indicate that four to eight eggs are laid in each puncture. They note also that most adults were present in June and early July in the Coachella Valley. The male cicada is conspicuous by the loud, shrill, and prolonged sound it makes, particularly on warm days. The adults feed by sucking the sap of various plants, but this action apparently does not noticeably harm the elm tree. Shortly after hatching the cicada nymph falls or crawls to the ground beneath the plant and burrows itself in. In the soil the nymph feeds during its long existence there by sucking the sap of various plant roots. So far as is known

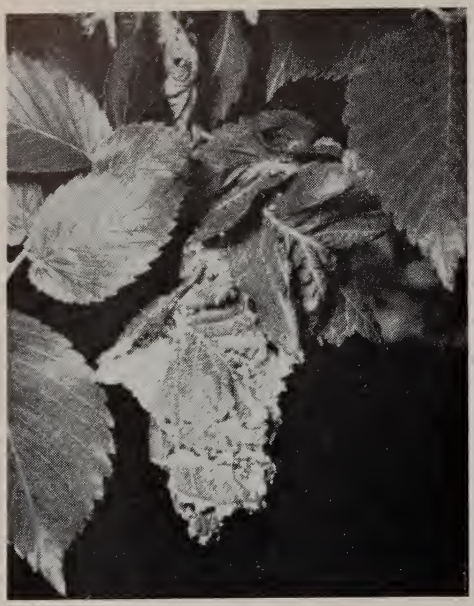


Fig. 4. A clump of American elm leaves, curled and galled by a white woolly aphid. (x 0.3)

no damage is done to the elm by such feeding.

Successful insecticidal control of this and other cicadas has been obtained with thorough-coverage sprays of dieldrin, chlordane, DDT, and Sevin (carbaryl). Control measures are directed against the adult stage when it is on the elm tree or likely to be there. See section on Control.

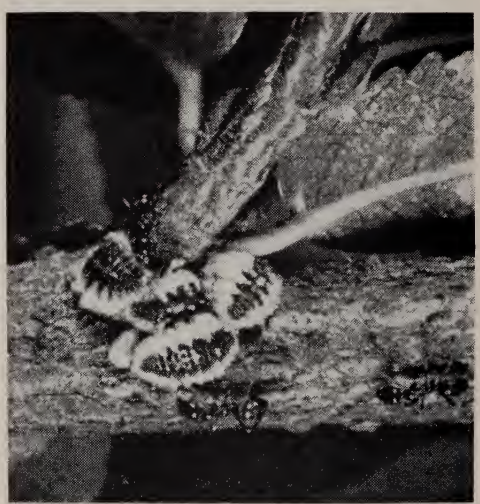
Woolly elm aphids

The woolly elm aphids, *Eriosoma* species (Homoptera: Aphididae), occasionally infest American elm in southern California (fig. 4). The terminal leaves are each curled toward the underside, and in this almost gall-like formation sometimes great quantities of fluffy, waxy secretions may be seen, with the aphids beneath this woolly mass and on the leaf surface. According to Gillette and Palmer (1934), one of two species may be found on elm: either *Eriosoma lanigerum* (Hausmann), the woolly apple aphid, or *Eriosoma americanum* Riley, the woolly elm aphid, both doing similar damage. The winged forms of the woolly apple aphid are pinkish to reddish-brown, the winged forms of the woolly elm aphid are dark green to almost black. The woolly apple aphid is very common also on many rosaceous plants, but it does not seem to have to go to these alternate hosts; whereas the woolly elm aphid apparently goes to serviceberry as an alternate host.

When control of these aphids is necessary, sprays of malathion or diazinon should be effective. Additional wetting agent in the spray—to aid penetration of the waxy secretions—and adequate spray pressure will be necessary with such thorough-coverage sprays. See section on Control.

European elm scale

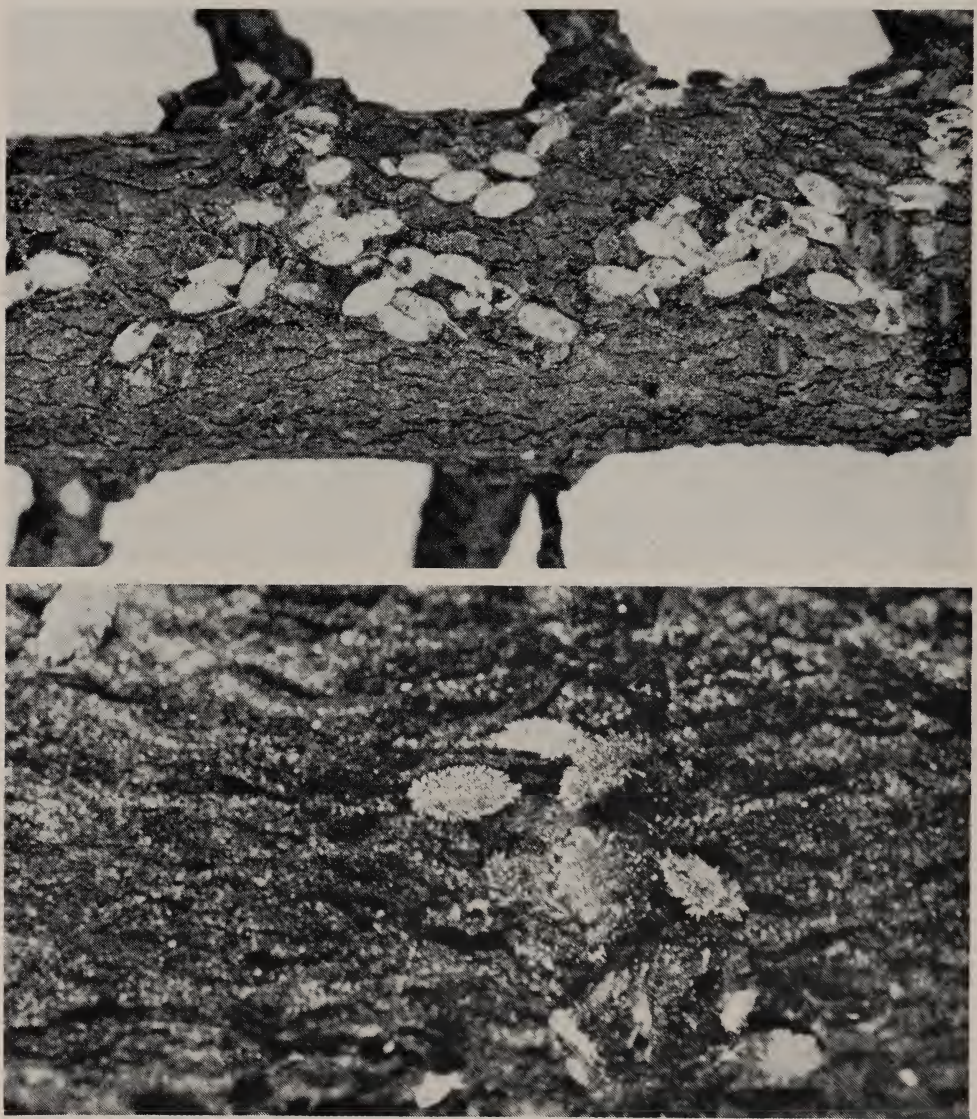
Eriococcus spurius (Modeer), the European elm scale (Homoptera: Kermidae), is perhaps the most important and most common sucking insect affecting the elm tree in southern California. The undersides of the limbs often are almost covered with the scale (figs. 5 to 7). Such infestations remove large quantities of sap from the tree, which devitalizes the tree generally and may cause a yellowing and dropping of leaves, and the killing of the smaller twigs and limbs. The scales produce great amounts of honey-



European elm scale. Fig. 5. Above: Mature females of the scale, with attending ants on Chinese elm. (x 4.5) Fig. 6. At right, top: Cocoons of the males. (x 4.6) Fig. 7. At right, bottom: Immature forms on elm twig; note resemblance to mealybugs. (x 14.0)

dew, which drips down on the leaves below or on lawn furniture, automobiles, and sidewalks beneath the tree. This sticky honeydew is a nuisance and also serves as a medium for the growth of a black smut fungus. Sometimes this fungus makes the limbs and leaves appear as if dusted with coal dust. The crawlers and other immature stages of the scale may also infest the lower surfaces of the leaves. All species of elm are attacked as well as species of hackberry and *Zelkova*.

The most conspicuous stage of the European elm scale is the mature female (fig. 5). It is dark reddish- or purplish-brown, and surrounded by a white cottony wax fringe which is most prominent along the sides of the body. Segments of the body can be seen, and these are further accentuated by points of the cottony fringe extending up on the back. The females are attached to the elm branch by their long and hairlike mouthparts. Apparently they do not use their legs. The female body length is about 2.5 mm. The male scale (fig. 6) has a somewhat more complex development than the female. In the adult stage the male looks more like a conventional insect: it has a pair of wings on the metathorax, and it uses



its well-developed legs to walk about on the limbs in search of the female. The male, too, is reddish-brown and about half the length of the female. The winged male frequently has a pair of waxy anal filaments that are almost as long as the body; these filaments may be seen projecting from a cocoon in the center of figure 6. In another type of male (Herbert, 1924) the wings are indicated only by small pads; this type usually does not have the anal filaments of the winged male, but the legs are well developed. The eggs, according to Herbert, are about ⅓ mm long and yellow. Another stage of the scale, sometimes observed in large numbers, is the mealybug-like immature stage (fig. 7) walking about slowly on the limbs and leaves. The immature scale attains a length of approximately 1 mm, and is reddish-brown with a fringe of whitish lateral and dorsal spines.

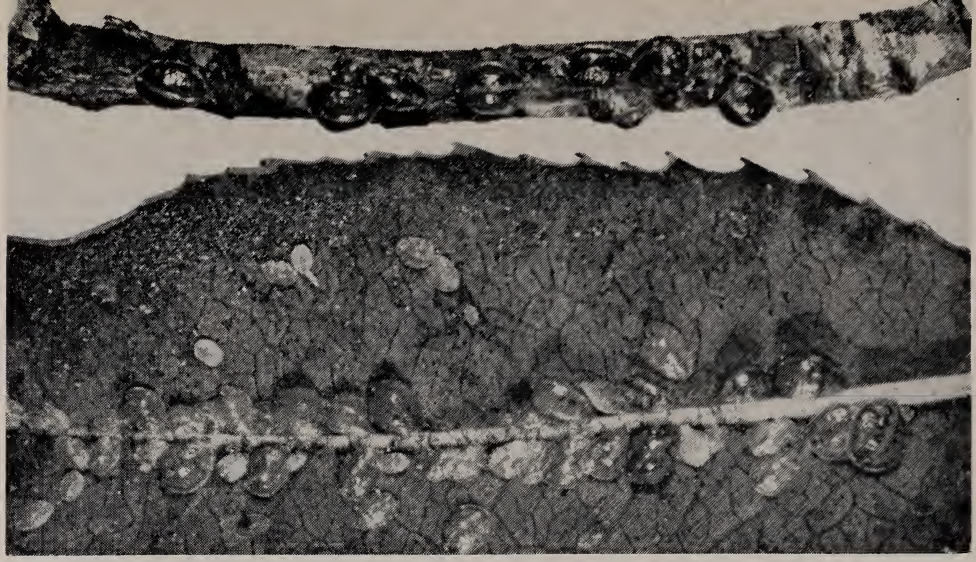
Herbert (1924) gives a complete account of the habits, life cycle, and seasonal development of the European elm scale; our observations bear out his findings. The insect overwinters in the immature stage (see fig. 7) in the bark crevices. The males and females attain maturity in the spring, in southern California generally from mid-March into April. After mating, which takes place shortly after the insect matures, the eggs develop in the female, causing her to swell in size. Oviposition is delayed almost to the time of hatching. Egg-laying continues throughout the summer, with the crawlers walking over almost all parts of the elm tree. After the eggs are laid, the female until her death keeps her mouthparts inserted into the vascular system of the twigs and limbs, and is sucking copious quantities of sap, and defecating it as honeydew. This may continue into the fall of the year. Only a single brood occurs annually, but dead scale bodies may persist on the limb for several years. If the female body contains no reddish fluid when squashed, it can be presumed to be dead.

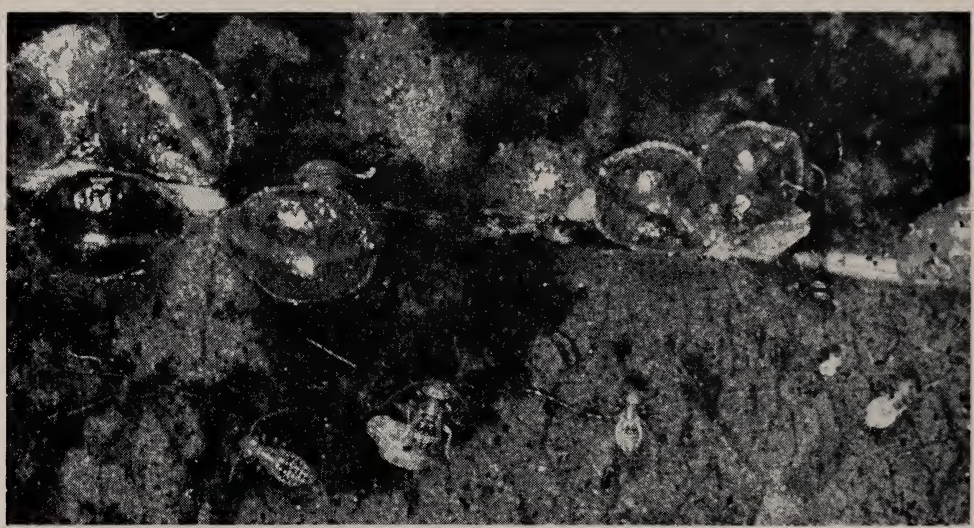
The immature stages of the European elm scale are the easiest to kill with insecticides. Dormant oils have been used in the past, and malathion alone can be used in the spring, or even DDT alone (the latter is not usually considered a good scalecide). However, combinations of either of these synthetic insecticides with 1½ to 2 per cent light medium oil has generally increased their effectiveness, against both crawlers and adults. Diazinon and oil is a promising combination spray and Sevin is also promising. Spraying should be particularly thorough. The use of additional wetting agent in the spray may improve coverage. Since ants are attracted to the honeydew, and they tend to promote scale infestations, some attempt should be made to control them with sprays of the above materials, or with dieldrin applied to the trunk area of the tree. See section on Control.

European fruit lecanium

The European fruit lecanium, *Lecanium corni* Bouché (Homoptera: Coccidae), greatly varies in size, shape (Ebeling, 1938), and coloration, and attacks a great variety of host plants, including all species of elm. This diversity has made possible the large synonomy of scientific names, and there may even be some question whether the scientific name we use is valid for the insect we are discussing (Richards, 1958). The European fruit lecanium is also among the most common and important economic insects, and one about which much has been published. It seems to be very common and destructive on the many economic plants in the rosaceous family. This coccid scale is a very prolific pest, and often is found on the smaller twigs and leaves in such numbers as to cover the twigs completely. It is a copious sap sucker and honeydew producer. Infested plants can be detected from a distance because of their blackened appearance (figs. 8 and 9), caused by the black smut fungus which lives on the honeydew. Many smaller twigs and limbs are weakened and killed by the attack of this scale insect.

Generally, females of the European fruit lecanium (figs. 8 and 9), when on a broad part of the host plant, are convex and hemispherical, although a little longer than broad; most specimens are 3 to 5 mm long. On a narrow twig the female body may be much longer than





European fruit lecanium. Fig. 8. Top: Adult and immature forms of females on leaf and twig of toyon; appearance and location of infestation is similar on elm. (x 2.6) Fig. 9. Center: A greater enlargement of adult and immature females; note black sooty mold and several psocids that feed on it. (x 6.4) Fig. 10. Bottom: Newly-emerged male and its cocoon; note wings and long white anal filaments. (x 13.2)

broad. The surface of the mature females is smooth and shining; sometimes it may have a slight dusting of powdery wax. Under the compound microscope, according to Lawson (1917), the most distinguishing character of *Lecanium corni* is an elongated group of pores running from the anal plates toward the head. He gives a good illustration of this, as does Dietz and Morrison (1916). The color of the scale body varies from yellow to dark brown, and frequently a lighter dorsal line can be seen which is bordered by indistinct, darker, mottled lines. Where the surface of the scale touches the host plant, the surface flares out slightly, like the edge of a bell. If one turns over the female scale, many eggs may be seen in the large concavity beneath the scale. There may be as many as 2,000 (Slingerland and Crosby, 1930) of these minute, ovoid, translucent white eggs, which appear like dust under the female. The immature stages of the female (fig. 8) are very much flatter and lighter colored than the adult. Some specimens of immature scales may show a considerable quantity of dustlike, powdery wax on their dorsum. If one searches diligently the flattened, scalelike "cocoon" of the male scale (fig. 10) may be seen; it is rather dull white, and frequently one can see the very long, waxy, anal filaments of the male protruding from beneath this cocoon. The male scale has three pairs of legs, and a pair of wings on the metathorax; both legs and wings are functional. The body of the male is approximately 1.6 mm long, and the length of a single wing is also 1.6 mm. The body is dark reddish-brown, and the wings are translucent white. The pair of wax anal filaments are white, and may be two to three times the length of the body. Apparently the normal mode of reproduction is by parthenogenesis, as the males are not at all common.

The European fruit lecanium produces one generation per year. The females reach maturity from early April through June; a few weeks after reaching maturity, usually from May into July, they begin to lay eggs (Habib, 1955). These accumulate in the cavity beneath the body of the female. Two or three weeks after oviposition the young crawler hatches, crawls out from under the female scale, and searches for a place to feed on the plant, selecting the more tender growth, such as the leaves and new stems. According to Habib, temperature can have a great effect on the time required by the egg stage and the two instars after hatching. The total of these periods varies from 83 days under warm greenhouse conditions, to as long as 568 days under cooler outdoor conditions (in England). Overwintering in southern California is most likely to be in the second immature instar, which is the period just preceding adulthood.

As with the insecticidal control of other scale insects, it is easier to kill the crawler, or other immature instar of the European fruit lecanium than it is to kill the adult. Oil sprays have long been used on many different plants in the dormant period. Shortly after hatch oil-malathion

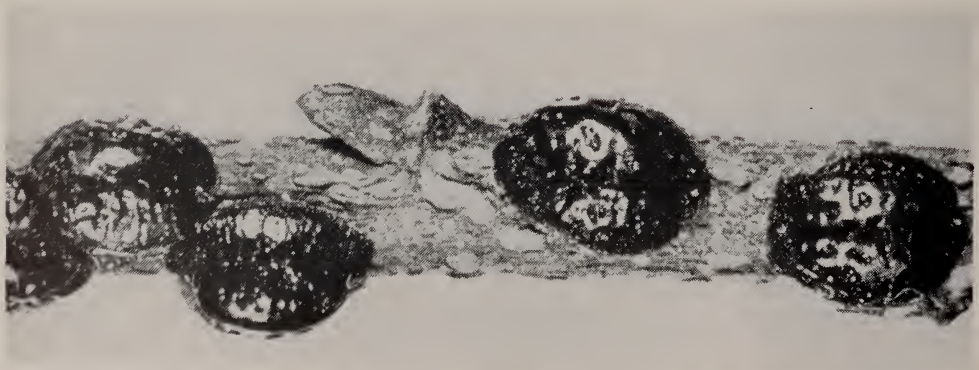


Fig. 11. Adults of the brown elm scale on a twig of hackberry. (x 4.6)

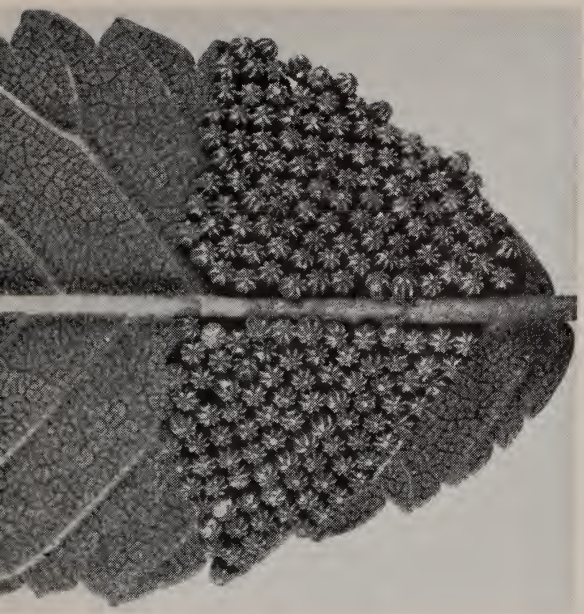
combination sprays are effective, as is a spray of oil-diazinon, or sprays of malathion or diazinon alone. Sevin (carbaryl) is an excellent insecticide against this and other members of this family of scale insects. See section on Control.

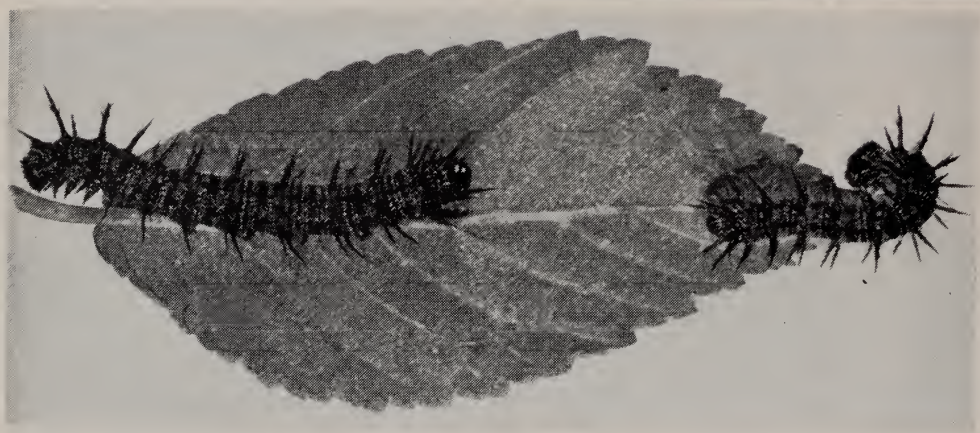
Brown elm scale

There is some question about the status of *Lecanium canadense* (Cockerell), the brown elm scale (Homoptera: Coccidae). Cockerell (1895) described *canadense* as a variety of *Lecanium caryae* Fitch. Essig (1958) lists *canadense* as a separate species, but he also notes that G. F. Ferris (a specialist in the Coccidae) considers it as a synonym of *Lecanium corni* Bouché (see page 8). Craighead (1950) gives both "European fruit lecanium" and "brown elm scale" as common names of *Lecanium corni*. Lawson (1917) lists *canadense* as a synonym of *Lecanium corni*. If what we are calling *Lecanium canadense* (fig. 11) is truly *Lecanium corni* (fig. 8), then this further illustrates the extreme variability of *Lecanium corni* mentioned on page 8. The specimens shown in figure 11 are black, with very dark brown showing in a few spots. Although the derm is very smooth and shining, many punctations are noticeable, even in the photograph. The specimens shown average 5.6 mm long, which is slightly longer than the usual *Lecanium corni*. They were found on hackberry (in the elm family) and we would say that the specimens similar to those shown are not particularly common in southern California. The control measures mentioned for *Lecanium corni* are also effective for *Lecanium canadense*. See section on Control.

LEAF-CONSUMING INSECTS

Fig. 12. Healthy elm twig (top) and one severely defoliated by the spiny elm caterpillar (bottom). (x 1.0)





Spiny elm caterpillar. Fig. 13. Top left: Egg mass on leaf. (x 4.4) Fig. 14. Top right: Pupa, suspended head down. (x 2.8) Fig. 15. Center: Caterpillars on elm leaf. (x 1.9) Fig. 16. Bottom: The adult, called mourning-cloak butterfly. (x 1.2)

Spiny elm caterpillar

The adult of *Nymphalis antiopa* (Linné), the spiny elm caterpillar (Lepidoptera: Nymphalidae), is one of the more common butterflies, and is known in the United States as the mourning-cloak butterfly. It is found around the world in the northern hemisphere (Field, 1938). The larvae are known to feed on the leaves of a wide variety of woody plants, including members of the elm family which seem to be especially favored. The larvae consume the leaves (fig. 12), and typically a branch may be completely defoliated by the numerous and gregarious larvae, while neighboring branches may be almost completely without injury. The homeowner may see the limbs of a favored elm tree defoliated, seemingly overnight. Not only is this caterpillar a common elm pest of some importance, but it has a nuisance value on elms grown in the homeyard, because the larvae may drop to the ground where small children may contact the spines on the surface of the caterpillar (see fig. 15); these spines have a mildly irritating effect on such tender skins. Often the presence of larvae in the trees is first detected by the dark fecal pellets on driveways, patios, and sidewalks.

The eggs are laid typically in clumps on the leaves (fig. 13) and limbs. The egg is pinkish to brown, almost cylindrical with eight longitudinal ribs, and is slightly rounded above. It is laid on end and is about 0.8 mm in diameter. The larva (fig. 15) at maturity is 34 mm long, and is black with a row of orange-brown spots down its back; four or more rows of minute white dots appear around each segment. The most conspicuous feature of the larva is the single row of stout, black spines around each segment; each spine is as long as the diameter of the segment. Each stout spine may have several smaller spines branching from it. This larval spininess is a characteristic of this butterfly family. The larval prolegs are orange. The angular-appearing pupa (fig. 14) is suspended head down from a small pad of silk, which may be spun on almost any convenient support; there is no cocoon. The dorsum of the abdominal segments has several stout spines, tipped in red, on each segment. The pupa is brown, and mottled with a purplish-gray. The adult (fig. 16) has a wingspan that varies from 55 to 70 mm. All parts of the body and wings are a uniform brownish-black (the reason for the name "mourning-cloak") except the following: the wings are bordered on the distal margin with a dull yellow band, which has some dark brown scaling, and inside of each band is a transverse row of pale blue spots; two dull yellow spots are near the apex of the forewing. There is a suggestion of a "tail" (like the papilionid butterflies) in the anal area of the hind wing.

Both Holland (1931) and Craighead (1950) state that the spiny elm caterpillar has two generations per year. In southern California it has at least this many, with considerable overlapping of broods. The adults have been seen during every month of the year in southern California, and it is in this stage that a type of hibernation occurs during our relatively mild winter. Larvae have been found in December and January and are commonly found during the early spring months, and pupae during May and June. Pupae may again be found during the early fall months.

The spiny elm caterpillar is very easily killed with all classes of modern insecticides: chlorinated hydrocarbons, organophosphorus compounds and carbamates. The usual practice is to spray the larvae when they are seen attacking the elm, during March and April. See section on Control.

Elm leaf beetle

Galerucella xanthomelaena (Schrank), the elm leaf beetle (Coleoptera: Chrysomelidae), is by some called the most important insect affecting the elm tree in California. There is little question that it is the most important leaf-consuming insect. This beetle of European origin was first found in California at Fresno in 1924 (Essig, 1958). Since then it has spread to most of the elm-growing areas of California. In what can be called "southern" California, the beetle has been found commonly in the southern end of

the San Joaquin Valley, also in Mono, Inyo and San Bernardino counties, the northern parts of Ventura and Los Angeles counties. So far as we know it has not been found established south of these areas. The beetle (both adult and larva) will feed voraciously (fig. 17) on the undersides of the leaves of any species of elm grown in California. It seems to do very well in the arid areas where elms are grown, and ironically it is in these usually warm areas that man most appreciates the shade of these rapidly growing trees, thus making the elm leaf beetle a truly vexing problem. Agricultural authorities of Los Angeles County, for example, have spent considerable effort and money to prevent the beetle from spreading into the Los Angeles plain. The fact that the beetle has not yet invaded this area is remarkable, considering the volume of automobile and truck traffic coming from infested areas along heavily traveled Highway 99.

The yellowish-orange eggs (fig. 18) of the elm leaf beetle are laid in clumps or irregular rows of a few to 30 eggs. Each egg is about 1 mm long, spindle-shaped, and is laid with one end attached to the leaf by a gluelike material. The larva at maturity (fig. 19) is about 8 mm long, yellow, with a black head and a black double row of tubercles along the sides. The tubercles are the base for a few whitish setae. These black tubercles seem to occupy more of the surface of the younger larvae (see fig. 19), with more yellow showing as the larvae grow older. The larvae have mandibles and feed on the leaf like the adults. The pupa (fig. 20) is approximately 5 mm long and is a dull yellow. The surface of the pupa has many, minute, black, seta-bearing tubercles. Sometimes the terminal part of the pupal abdomen may be encased in the cast larval skin, but otherwise no sort of cocoon or other pupal protection is found. Under a heavily infested tree there may be so many pupae in the debris around the trunk that the pupae are piled several deep. The adult (figs. 19 and 21), when newly emerged, is marked contrastingly with bright yellow overall and black spots, but with age the yellow turns a dark olive-green. Each elytron has a wide

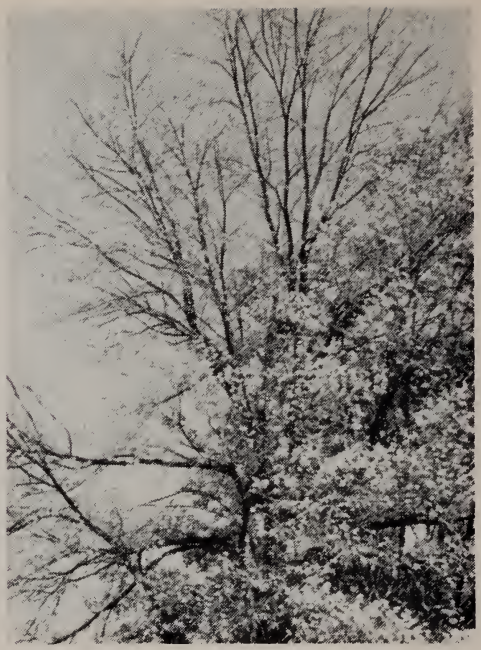
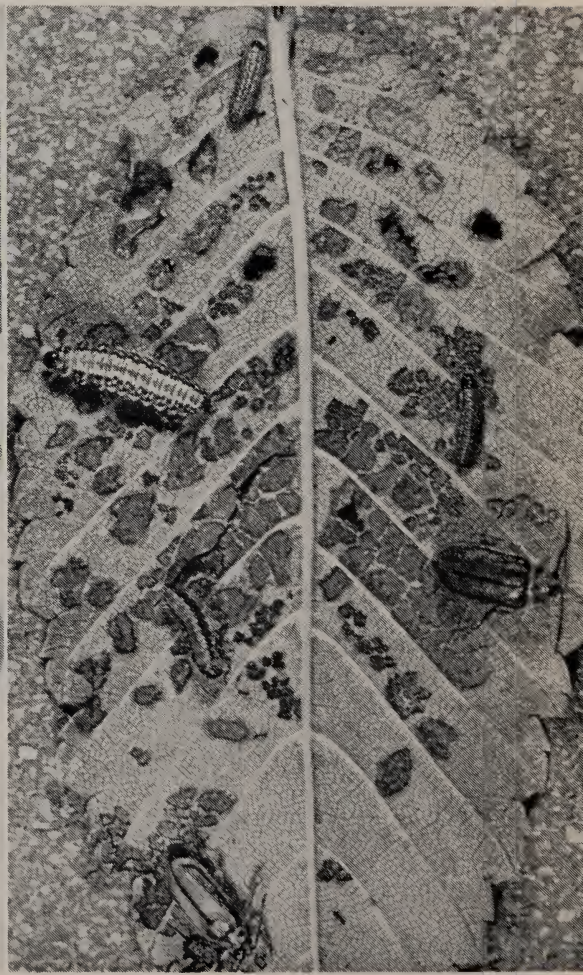


Fig. 17. An American elm almost completely defoliated by elm leaf beetles.

Elm leaf beetle. Fig. 18. Below: Clump of eggs on lower side of leaf; none of these have hatched. (x 4.7) Fig. 19. At right, top: Larvae, adults, and injury of the beetle. (x 2.6) Fig. 20. At right, center: Pupae taken from debris at the base of a tree. (x 4.5) Fig. 21. At right, bottom: The adult beetle. (x 5.3)



black mark along the outside margin, and a narrow black mark along the inside edge, where the elytra join together. Near the base of the elytron is an oval black spot. The prothorax has a black T-shaped mark centrally, and a circular black spot near each lateral margin. The vertex of the head is black. A black linear spot marks each of the segments of the legs and antennae. The adult is approximately 6 mm long.

Essig (1958) states that the elm leaf beetle produces two to three generations annually, with indications that a fourth brood may occur. Mackie (1927) indicates that as many as five broods can develop within one year in California. The insect overwinters in the adult stage, and can be found in any natural situation that is sheltered and dry. Barns, sheds, and attics of homes are favored overwintering sites, if they are near the elm tree; sometimes many hundreds of lethargic adults may be found in these locations. In the warm days of spring (mid-March into April), as the leaves are becoming well expanded, the adults fly to the leaves from their hibernating places. Mating, oviposition, and some feeding on the leaves take place. According to MacAloney (1950), the egg stage occupies about a week, the larval stage two weeks to a month (depending upon temperature), and the pupal stage about ten days. By late summer the leaf skeletonizing injury is very apparent (fig. 17).

Thorough-coverage sprays for controlling the elm leaf beetle should be applied beginning in the late spring and repeated as needed. For spraying mature American elms a high-capacity spray rig is necessary, usually with spray rods (Brown and Eads, 1965). A variety of modern insecticides are available that are effective against the elm leaf beetle, such as DDT, BHC and dieldrin (chlorinated hydrocarbon insecticides, for long residual effect); malathion (phosphate insecticide); and Sevin (carbaryl, a carbamate insecticide). According to Koehler *et al.* (1965) Sevin is an excellent insecticide against this insect; a single application made in early June gave leaf protection for the rest of the season. See section on Control.

BORING INSECT

Smaller European elm bark beetle

In southern California *Scolytus multistriatus* (Marsham), the smaller European elm bark beetle (Coleoptera: Scolytidae), is the most serious insect pest of the elm tree. This small, prolific, and aggressive beetle is a particularly serious pest of elms suffering from drought, and has caused the death of many such trees. Drought, a common condition in this area, has affected both wild and cultivated plants for more than a decade. Contrary to popular belief, very few insects exist whose attacks result in the death of shade trees. But this bark beetle is one of them; at least, it can be the most important factor in such deaths. Therefore this pest should not be taken lightly. Sometimes the first notice of a bark beetle infestation is the general weakening of the leaves, or their absence, on the smaller limbs. On closer inspection many "shot holes" (as though made by bird shot from a shot gun) may be found in the bark of the smaller or larger limbs, or in the trunk (fig. 22); and the limb crotches may have a considerable dusting of fine reddish brown, powder-like frass. If, in peeling the elm limb bark with shot-holes (fig. 24), you find a single engraved tunnel without frass, running parallel with the wood grain, and perpendicular to this many, smaller, frass-filled tunnels, you have most likely discovered bark beetle infestation. If, besides this typical centipede-like en-

Fig. 22. Numerous shot holes of the smaller European elm bark beetle on Chinese elm; lateral tunnelling near center was beneath bark plate that later came off. (x 0.9)

graving, you find the typical adult beetle (fig. 27) crawling in its tunnel or on the bark, then you have without question discovered the cause of the damage. If enough of the typical tunnelling occurs around the trunk, the water and food transport functions are disrupted, the trunk is girdled, and the tree dies.

A mature elm (see a portion of its trunk in figure 23) was found to be severely infested, as were two neighboring elm trees; they were also suffering from insufficient irrigation. The trees were sprayed immediately with a recommended insecticide, and the soil beneath them was given a deep irrigation for several days. The water taken up by the tree was soon seeping out of the shot-holes, as shown in figure 23, which also suggests the great number of such holes present. These actions saved two of the trees, but the third was beyond saving and had to be cut down. The cut wood was destroyed, as developing beetles are able to complete their life cycle in such wood, and to reinfest other trees.

This European beetle was inadvertently brought to America about 1909, and has gradually made its way across the continent. In California it was discovered first in San Jose in March 1951. Approximately a year later it was found in southern California, and now it can be found throughout this area. Infestations have been confirmed in several species of the genus *Ulmus* and in *Zelkova*.

The beetle is among the shade tree pests studied most widely in America, because it is the most important vector (carrier) of the dreaded Dutch elm disease (caused by the fungus, *Ceratocystis ulmi* (Buism.)), which has killed many elms in the northeastern United States. Fortunately, as far as is now known, the smaller European elm bark beetle did not bring along this disease on its journey to California, but everyone in this state should be alert for any sudden wilting of leaves and death of limbs of their elms, and should report this immediately to the

Fig. 23. Each dark spot is water oozing from a tunnel of the smaller European elm bark beetle on a trunk of Siberian elm. The drought-stricken and infested tree had been heavily irrigated. (x 0.18)

Agricultural Commissioner of his county. It is not known whether the disease, if it should get to California, would establish itself in this rather arid region, as it did so successfully in the more humid northeastern area of the United States. Thompson *et al.* (1961) state that elms of Asiatic origin (*Ulmus pumila* and *U. parvifolia*) are resistant to the disease whereas the American elm (*U. americana*) is quite susceptible. For up-to-date reviews of the Dutch elm disease, and the relation of *Scolytus multistriatus* to it, see Thompson *et al.* (1961) and Sauvé (1964).

The smaller European elm bark beetle, like many other scolytid beetles, is easily identified, even by the layman: the beetle is restricted to a narrow range of host plants, and makes a rather unique engraving on these hosts. The tunnelling is at the junction of the bark and the wood; when the two are separated, both appear to have been engraved with a distinctive pattern by the beetle and its progeny. The tunnel made by the adult female is straight, runs with the grain of the wood, and may be 1 to 2 inches long (fig. 24). She is very tidy and keeps the tunnel free of frass, by pushing these powder-like bits to the outside of the tree through the entrance hole.

As inferred by Chamberlin (1939), mating of the sexes occurs on the bark surface (rather than in the tunnel as some scolytids do), so that the tunnel is primarily for egg-laying, and for feeding. Adult beetles are often seen, sometimes in great numbers, on the outside of the bark. Many can be seen entering open holes in the bark, then emerge again and often may enter another hole. This activity takes place usually before and during egg-laying, and is a good time to control the pest with insecticides. After boring the tunnel the female beetle chews out a concave depression in the side of the tunnel and lays a rather large (compared to her size), ovoid, almost spherical, whitish egg in the depression. The minute wood pieces she bites out in making the concavity, are packed tightly around the egg, so that the surface of the tunnel is smooth. She repeats this process two to eight dozen times up both sides of the tunnel, so that the sides of the tunnel are completely filled with incubating eggs.

When the larva hatches it bores laterally away from the oviposition tunnel (fig. 24). As it bores in the wood-bark junction the larva displaces its volume in these tissues by defecating and leaving behind the brownish, powder-like frass which is tightly packed in the tunnel. This is apparent by the increasing size of the larval tunnel, as it leads away from the oviposition tunnel, and by the increase in larval size. The larval tunnels, because of some unknown sense of the larva, seldom touch each other, and tend to spread or fan out rather evenly from the oviposition tunnel, so that the pattern of engraving is rather oval at its outer limits. When the larva is at the outer limits of its mine it is legless, C-shaped, fat and wrinkled, with the thorax being the thickest part of the body, and translucent white (fig. 25). The head is sunken largely into the prothorax, the most prominent part of the head being the dark and powerful mandibles. The mature larva is about 5 mm long if straightened out.

As pupation approaches the larva begins to bore toward the outside of the tree, that is, into the bark. A short distance into the bark a pupal chamber is hollowed out, and pupation occurs. The pupa (fig. 26) is translucent white, rather stubby and humped, and with two rows of spines along the dorsum of the abdomen. The pupa is approximately 4 mm long. The adult emerges in the pupal chamber and chews its way to the bark surface. The adult (fig. 27) is approximately 3 mm long, but considerable variation above and below this has been observed. Some variation in color has also been noticed, but most adults are dark brown, to almost black. Like most scolytids, it is a stubby appearing beetle, and the rather short abdomen ascends abruptly ventrally and posteriorly (it is almost concave from a lateral view). The most unusual feature of the adult is a prominent ventral spine, arising from the second abdominal sternite, and projecting posteriorly; the function of this spine is unknown. Another common, similar scolytid, the shot-hole borer, *Scolytus rugu-*

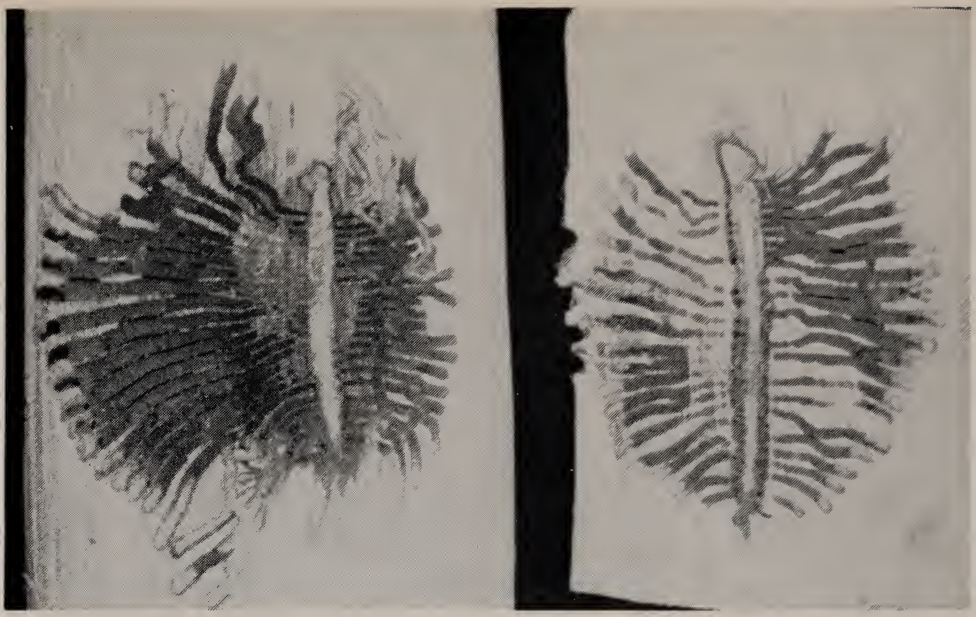
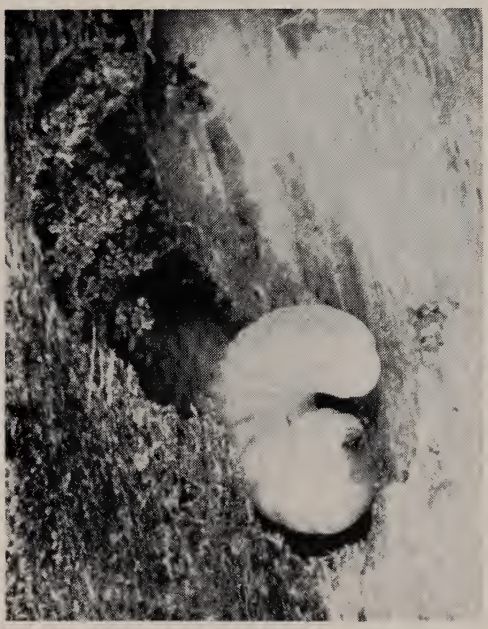
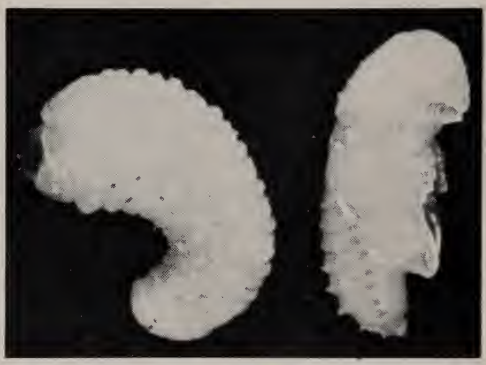


Fig. 24. The bark is removed to expose egg-laying tunnel (with the grain) of the smaller European elm bark beetle, and the numerous frass-filled larval tunnels (across the grain). (x 2.1)





Smaller European elm bark beetle. Fig. 25. Above: Larva exposed by slicing into the bark. (x 8.7) Fig. 26. At right, top: Larva and pupa removed from its chamber in the bark. (x 9.6) Fig. 27. At right, bottom: Adults; note ventral keel projecting to rear. (x 12.7)

losus (Ratzeburg), could be confused with the elm bark beetle, except that *S. rugulosus* lacks this ventral spine and attacks only rosaceous plants, such as plum and apple.

Figures 22 and 24 indicate what the bark looks like when all of the progeny become adults and bore to the outside: not only does the size of each hole but the grouping of the holes, suggest the tree has been shot with a shotgun. Also it is easy to realize the adverse effects on the elm tree when many such adult and larval engraving patterns are interlaced around the limb or trunk.

Blackman (1950) lists two and a partial third generations of the smaller European elm bark beetle in the vinicity of northern New Jersey. Chamberlin (1939) lists two broods. It is interesting, considering the milder conditions and longer growing season in southern California, that the same number of broods annually have been noticed here, that is, two and a partial third (Brown, 1965). Thompson *et al.* (1961) indicate what could be interpreted as almost three generations in Kansas. The broods (i.e., flights of adult beetles) appear six weeks to two months earlier in southern California than in the northeastern United States. In southern California, the peak of the first brood (which is the smaller) occurs about mid-April, with the build-up beginning in late March, and the second brood peaks in early July. The partial third brood in southern California overlaps to a considerable extent with emerging adults of the second brood. Mature larvae, pupae, and adults have been observed throughout the winter months in southern California, although Blackman (1950) and Chamberlin (1939) note that the larva is the usual overwintering stage in northeastern areas of the United States.

Prevention of infestation of this elm bark beetle, as with most boring insects, is usually easier and more effective than control after infestation. As pointed out earlier, the beetle prefers trees that have been weakened in some manner—especially drought in southern California. Make certain that elm trees are not suffering from dought by a program of adequate irrigations during the year. Make pruning cuts clean, that is, leave no stubs or broken limbs and stripped bark; it is probably of benefit to paint pruning wounds with some sort of asphalt-containing pruning compound. Prevent automobiles, mowing machines, or cultivating equipment from bruising or cutting the tree. Fertilize the soil under the tree to insure strong, vigorous growth. Burn dead or dying trees or limbs, infested with the beetle, or spray them with lindane if they are to be used for firewood; such untreated, cut wood is a common source of reinfestation.

Insecticidal control measures should be considered as secondary to the cultural practices mentioned. As with most boring insects most efficient insecticidal control measures are aimed at stages of the insect that are outside of the plant tissue—the adult stage on the bark, in the case of this elm bark beetle. Thus, the proper timing of sprays is very important. In southern California insecticidal sprays should be applied, for the first brood, in late March or early April, and, for the second brood, in mid-June. DDT is an excellent insecticide and has been used against this beetle for over 15 years (Metcalf *et al.*, 1951, Whitten, 1963, Thompson *et al.*, 1961). Methoxychlor is equally effective in controlling the feeding of this beetle, and is much less hazardous to fish and wildlife (Whitten, 1963); Koehler *et al.* (1965) report leaf injury with this material, however. Lindane is an excellent insecticide against this (Doane, 1958) and other scolytids (Lyon, 1959). Dieldrin is very effective, and also has a very persistent residue on the bark. See section on Control.

CONTROL OF ELM INSECT PESTS

The following recommended insecticide dosages for the control of elm insect pests are listed roughly in the order of length of experience with the material, and taking into account its insecticidal effectiveness, and its harmfulness to plants and higher animals. No doubt some materials lower on the list will replace materials higher on the list when more is learned of their use. Consult the section on a specific insect for timing of sprays. All dosages are amounts per 100 gallons of water or more accurately, 100 gallons of finished spray. All recommendations are for thorough-coverage, conventional, high-pressure spraying.

Always read the insecticide package label, for directions for use, as well as precautions to be followed. If directions on the label differ from recommendations in this bulletin, follow the directions on the label.

WARNING ON USE OF PESTICIDES

These recommendations for pest control are based on the best information currently available for each pesticide listed. Treatments based upon these recommendations should give adequate control and not cause any serious hazard if the applicator follows all directions on the insecticide package label with respect to dosage levels, number of applications, and precautions for the user as well as those for fish and other wildlife.

The applicator is legally responsible for treatments on a given property as well as for problems caused by drift from original property to other properties or crops.

INSECTICIDE DOSAGES FOR CONTROL OF SUCKING INSECTS

Insecticide and formulation	Dosage/100 gal water	Remarks
1. Oil, light medium, emuls.	3 gal	Winter treatment of scales
2. Oil, light medium, emuls. *plus* Malathion, emuls. conc. (8 lb/gal), *or* wett. powd. (25%)	1½ gal 1½ pt 4 lb	Scales, aphids
3. Oil, light medium, emuls. *plus* diazinon, emuls. conc. (4 lb/gal), *or* wett. powd. (50%)	1½ gal 1 pt 1 lb	Scales, aphids
4. Sevin (carbaryl), wett. powd. (50%)	2 lb	Cicada, lecanium scales
5. DDT, wett. powd. (50%)	2 lb	Cicada
6. Dieldrin, wett. powd. (50%)	1 lb	Cicada; spray trunk for honeydew-feeding ants

INSECTICIDE DOSAGES FOR CONTROL OF LEAF-CONSUMING INSECTS

Insecticide and formulation	Dosage/100 gal water	Remarks
1. DDT, wett. powd. (50%)	2 lb	Treat at first notice of injury
2. Sevin (carbaryl), wett. powd. (50%)	2 lb	Same as above; preferred near fishponds
3. Lindane, wett. powd. (25%)	2 to 4 lb	Treat at first notice of injury
4. Malathion, wett. powd. (25%), *or* emuls. conc. (8 lb/gal)	4 to 6 lb 1 to 2 pt	Same as above; may be necessary to repeat spray

INSECTICIDE DOSAGES FOR CONTROL OF BORING INSECTS

Insecticide and formulation	Dosage/100 gal water	Remarks
1. DDT, wett. powd. (50%)	2 lb	Timing of spray essential; treat trunk and limbs
2. Lindane, wett. powd. (25%)	2 to 4 lb	Same as above
3. Methoxychlor, wett. powd. (50%)	2 lb	Same as above; may injure foliage
4. Dieldrin, wett. powd. (50%)	1 lb	Timing of spray essential

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To simplify this information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

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